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SOFTWARE DESIGN TO CALCULATE OF VIBRATION FOR A MORE EFFECTIVE ASSESSMENT OF THE SAFETY OF THE WORKING ENVIRONMENT

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Research article

Abstract: A lot of software that is developed simultaneously with the development of new measuring devices are very difficult to control. The results obtained from the software for measuring the vibration must be adjusted for the respective weighting factors which is very complicated and time consuming. This paper deals with design of software to calculate human exposure to vibration in the working and living environment. Presented software developed at the Institute of Integrated Safety, which counts with all the weighting factors. It allows quick results without aftertreatment weighting factors. Presented software includes all known methods for calculating the vibration acceleration. It's based on knowledge of the protection of man and his health against the negative effects of vibration. The measured data are evaluated according to the current legislation of the European Union. Simple layout software doesn't have a good first impression, but it's control is very swift and practical. Every reader needs to read about it below.

Keywords: Vibration, software, calculation, chart, frequency.

Introduction

In general vibrations are defined by vibration amplitude, velocity and acceleration. In practice, it is easier and more appropriate if the measurement is oriented to detect vibration acceleration. Measurement of vibration acceleration enables quick calculation provided for determining values for the determination of human exposure to vibration. For calculation of this in the world, but also within the European Union there are derived formulas. Harmonized relevant standards allows the use of established patterns in all Member States as well (Žiaran 2008).

The authors of this article presents a proposal software called VibroSoft. This name may not be the best choice, but this tiny software launch screen (Figure 1) conceals a large number of complex calculations (Publications of the European Communities, 2008), (Brauch, 2009).

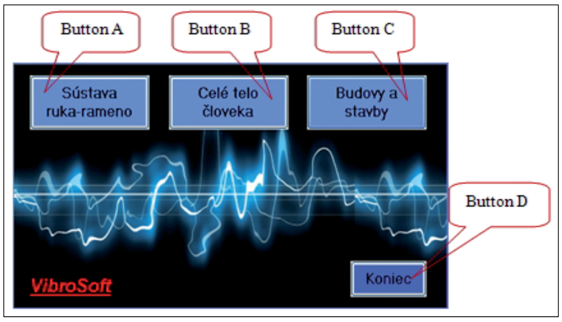

Fig. 1 Initial window to enter the software VibroSoft: Button A- The system of hand - arm, Button B - The whole human body, Button C - Buildings and sructures, Button D - End

Software presented in this article, operates using the formulas in the exposure level:

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The system of hand - arm

Calculation of acceleration is realized by calculating the equivalent frequency-weighted acceleration in a_{hwi} [m.s^{-2}]. The calculation is done for all the *x, y, z* of formula (1):

$$a_{hwi} = \sqrt{\sum_i \left(W_{hi} \cdot a_{hi}\right)^2} \tag{1}$$

where: W_{hi} - stands for the weighting factor for the *i*-th one-third octave band, a_{hi} - measured effectively acceleration of v *i*-the 3th part of octaveband in [m.s^{-2}].

The resulting acceleration equivalent a_{hv} [m.s^{-2}] formula (2) is made up of the components a_{hwx}, a_{hwy}, a_{hwz} (ISO 2001).

$$a_{hvi} = \left[\left(k_x \cdot a_{hwxi}\right)^2 + \left(k_y \cdot a_{hwyi}\right)^2 + \left(k_z \cdot a_{hwzi}\right)^2\right]^{1/2} \tag{2}$$

Normalized acceleration $a_{hv,Tn}$ [m.s^{-2}] formula (3), input is a_{hvi} and duration of work operations *T* [s]. T_n is reference time within the 8 hour work shift which represents the value of [28 800 s] (ISO 2001), (Law, 2005).

$$a_{hv,Tn} = \left(T/T_n\right)^{1/2} \cdot a_{hvi} \tag{3}$$

The entire human body

The formulas for the calculation of the acceleration are the same as for the hand-arm system. Changing the sign on the frequency-weighted acceleration a_w [m.s^{-2}], and marking the weighting factor W_i. Determination of daily exposure to changes in the labor $a_{w,8h}$ [m.s^{-2}] is calculated according to the formula (4):

$$a_{w,8h} = k_i \cdot a_w \sqrt{\frac{T}{T_0}} \tag{4}$$

where: k_i - is a multiplication factor, *i = x, y, z*, *T* - is the daily exposure time [s], T_0 - is the reference time of 8 h, the length of the workday to 28800 (ISO 1999).

The software calculates the dose fourth square acceleration value (*VDV* - Vibration Dose Value), the unit is [m.s$^{-1,75}$] or [rad.s$^{-1,75}$]. The frequency weighted acceleration then apply the denomination in all directions VDV_x, VDV_y, VDV_z, which is defined by the formula (5).

$$VDV_i = \left[\sum \left(W_i \cdot a_i\right)^4\right]^{\frac{1}{4}} \tag{5}$$

VDV_{exp} daily exposure value is defined by the formula (NF EN, 2004) (6):

$$VDV_{\exp} = k_i \cdot VDV_i \left(\frac{T_{\exp}}{T_{meas}}\right)^{\frac{1}{4}} \tag{6}$$

where: T_{exp} - is the duration of exposure during the working shift [s], T_{meas} - is the measured time [s] (ISO 1999).

Evaluation of vibration of the Foundation, the total VDV_{total} formula (7):

$$VDV_{total} = \left(\sum_j VDV_{\exp, ji}{}^4\right)^{\frac{1}{4}} \tag{7}$$

where: $VDV_{exp,ji}$ - is a partial data of daily exposure values for *i* = 1, 2, 3, ... *n* to the sources of vibration intended for all axes *j = x, y, z* of the source of vibration (Brauch, 2009), (ISO, 2004).

Vibration operating in buildings and structures

Calculation of frequency-weighted acceleration a_w [m.s^{-2}] according to the formula (1), which is used in both cases *A* and *B*. The frequency weighting changes sign at W_m. The calculation of the normalized acceleration in this case is not being realized. The frequency weighted acceleration a_w [m.s^{-2}] are established under the legislation of each country (Law, 2005).

All described formula including correction factors and weighting factors are programmed in software VibroSoft. When the user selects the appropriate button A, B, C, D key to exit.

Materials and methods

Measurements must follow the requirements of the ISO standard and the measured values must be corrected weighting factors. Individual frequency weighting factors are divided as follows: the transmission of vibration to the hand is a weighting factor W_{hi}, when the vibrations transmitted to the whole body of man is the weighting factor W_k, W_d, W_f the basic method and W_c, W_e, W_j for VDV method - Vibration Dose value. In the calculations of the weighting factors are selected in a range of 0.5 to 80 Hz. The values obtained measurements are processed in accordance with ISO standards.

Calculation using weighting factors with a large number of measured values is very complicated. The calculations take a long time. It was therefore designed this simple software which is called VibroSoft. The software was proposed by Microsoft Visual Studio.

Microsoft Visual Studio is a suite of tools for creating software, from the planning phase through UI design, coding, testing, debugging, analyzing code quality and performance, deploying to customers, and gathering telemetry on usage. These tools are designed to work together as seamlessly as possible, and are all exposed through the Visual Studio Integrated Development Environment. Coding example is the (Figure 2) (Visual Studio 2015).

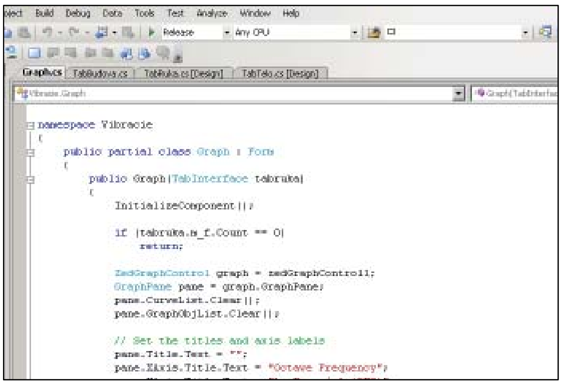

Fig. 2 Example writing code for software design VibroSoft

For the programming in Visual Studio was used programming language C#. C# (pronounced "C sharp") is a programming language that is designed for building a variety of applications that run on the .NET Framework. C# is simple, powerful, type-safe, and object-oriented. The many innovations in C# enable rapid application development while retaining the expressiveness and elegance of C-style languages (Visual Studio 2015).

The modern object-oriented programming languages like C++, C# and Java, are designed to provide major advantages in commercial software development and engineering application (Prabhakar Rao, 2009).

The values to validate software functionality VibroSoft were processed directly from the instrument CoCo-80 vibration data collector.

Results and discussion

At the beginning, there are profiles for software design VibroSoft (Figure 3). In the diagram are various steps in the design logically linked together. These steps are sequentially programmed the software itself. For the software design Microsoft Visual Studio was used. Using the programming language C# there has been created individual parts to calculate human exposure to vibration.

On opening software window (Figure 1) are four basic buttons for simple, but very effective control. The user chooses the button depending on what measured values he/she wants to process. When the user performs the measurement of the transmission of vibrations to the hand and arm, clicks A. These buttons are described above in the introduction to the article (Figure 1). By clicking the following button always displays the main work area VibroSoft (Figure 4). As an example, see (Figure 4) click on the button and open the main area.

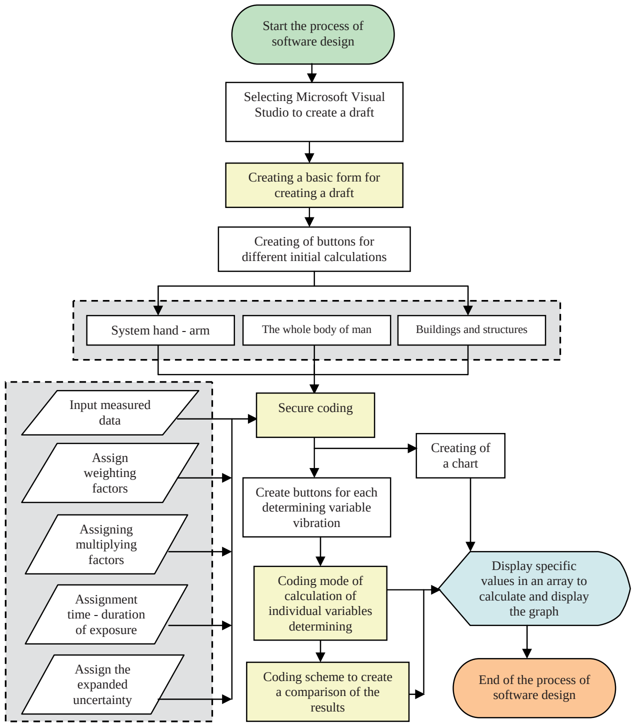

Fig. 3 Diagram for software design Vibro Soft

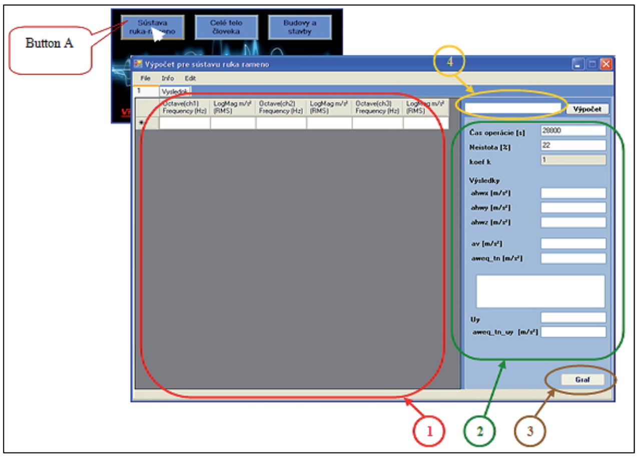

Fig. 4 The main working area of the program VibroSoft

The main work area is divided into four parts as seen in (Figure 4). To understand the function of the parts VibroSoft see the describtion:

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Part 1 - Box of measured data

This mailbox stores measured data to your device (Figure 5). Data generated from the analyzer are arranged in six columns. The bus includes the frequencies in a given frequency range (frequency range depends on the type of measurement) for all the *x, y, z,* and the measurement of the *RMS* value of the acceleration efficiency for the *x, y, z*.

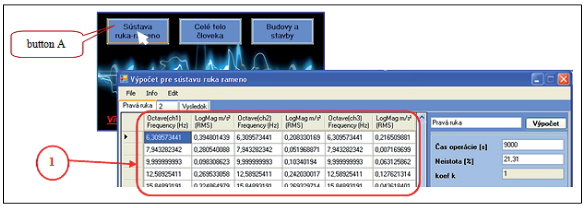

Fig. 5 Saving of the measured data in the clipboard - Part 1

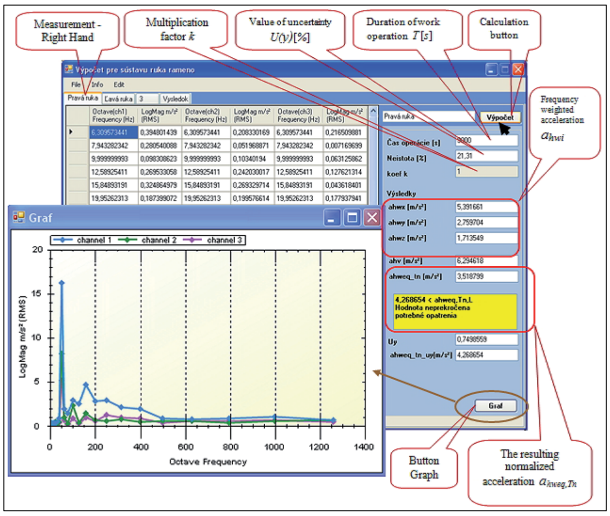

Fig. 6 Test Calculation of the resulting normalized acceleration $a_{hweq,Tn}$ - generating graph

Part 2 - Place for calculating of the determining variables

In this section are generated all the necessary acceleration values, which are obtained by calculation of the values stored in the clipboard. In this section you can change the exposure time *T* [s], the multiplying factor k value of the expanded uncertainty *U* (*y*) [%] (ISO 1999).

This section shows the normalized value of the resulting acceleration $a_{hweq,Tn}$ [m.s^{-2}] which is the comparison of permissible values automatically colored by depending exceed the limits, then:

- Green color indicates that the action level is not exceeded,
- Yellow color means the action level is exceeded, but does not exceed the limit value,
- Red color indicates that the limit value is exceeded.

Color coding is useful in terms of immediate inference result. The calculation (Figure 6) shows the value of the resulting normalized acceleration $a_{hweq,Tn}$ [m.s^{-2}] tinged yellow (ISO 2001).

Part 3 - button generates a graph

Charts can be generated to store the measured data to the clipboard. This is a simple graph, the dependence of the acceleration ai unweighted (*RMS* value) of the frequency measured in all directions *x, y, z*. An example of the generated graph is on (Figure 6).

As an example of using the main desktop VibroSoft were used real data measured under the effect of vibration on the hand of man. Measurements were carried out by the forest plant worker who works with a chainsaw. At (Figure 6) is shown storing data in a mailbox labeled measurement on the right hand worker and subsequent calculation determining variables.

Part 4 - The field for the marking of the measurement

If the measurement of vibration exposure to the hands, the box can write the type of source of vibration, or measuring the right or left hand worker (Figure 7). When measuring the impact of whole-body vibration, impact or vibration inside houses, in this box can be noted there on the name or type of source or location for the human body to assess the impact of vibration. After writing the name of the measurement, this name will automatically appear as the name of the mailbox measured data which is under construction (Figure 7).

If the calculation is necessary for both hands of employee or for multiple sources of vibration, just click on the number 2. Click to see a new main desktop, empty shell measured data, empty box for the marking of the measurement, which can be written as new name (Figure 7).

Measurement called [right hand], thus has a serial number and a new one inserted measurement number 2 after insertion of a new measurement, the program automatically assigns the next to its name the new key serial number 3. On (Figure 7) the procedure for the selection of new desktop called [left hand]. In this way, we can choose infinitely many new items.

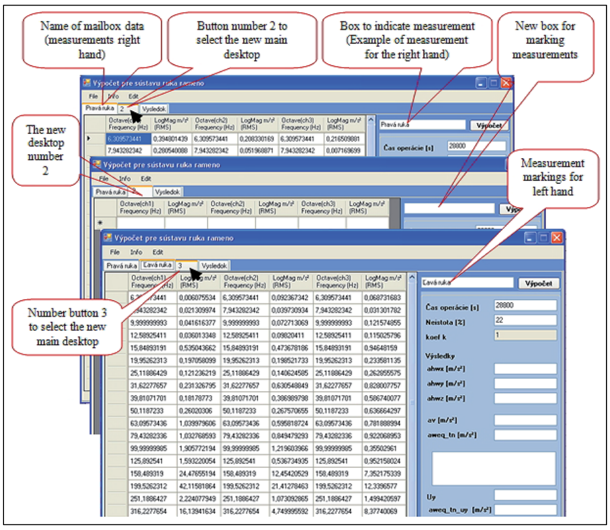

Fig. 7 Procedure for choosing of the new desktop called - Left Hand

Conclusion

Vibrations as a fundamental physical factor are an integral part of living and working environment of man. It is therefore necessary to provide the continuous monitoring in order to minimize the need for human. Early prediction of a proper assessment of the impact of vibration depends primarily on the accuracy of the measurements and processing results.

Software called VibroSoft is an effective form to achieve fast and accurate processing of measured data. Its application is very useful in the field. Working with VibroSoft presented in the text of the article is very simple and it saves time, which is a big advantage. VibroSoft is used in our Department of Safety Engineering for the safety assessment of real operations, along with the use of other methods of risk analysis. Our aim is that this article was beneficial in assessing the safety of the working environment of man. In the near future we publish more articles that deal with this issue.

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